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EVALUATING A MOUNTAIN PINE BEETLE INFESTATION WITH THE AID OF 35MM AERIAL PHOTOGRAPHY

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INTRODUCTION

The mountain pine beetle, Dendroctonus ponderosae Hopk., has been epidemic in the Intermountain Region for almost 20 years. The first large outbreak occurred in 1953 on the Wasatch National Forest in Utah, and since that time, new infestations developed and spread throughout most of the lodgepole pine type in Utah, western Wyoming, and southern Idaho. The single most damaging infestation began on the Targhee National Forest, Idaho, in 1958 and continues to this day. Control efforts were initiated in 1962 and continued through 1970. Most of the earlier control attempts were unsuccessful, partially due to inadequate financing, but principally due to a lack of understanding of the dynamics of this insect and its role as a natural regulator of lodgepole pine. Once this was understood and certain management objectives were redefined, a new suppression strategy was implemented in 1967. Instead of attempting to suppress well established beetle populations, efforts were shifted to the north, in the Warm River Area, where the stands were relatively beetle-free but directly in the path of the advancing infestation. Here it was hoped that, with an intensive effort, tree killing could be maintained at a relatively low level until most of the threatened timber could be harvested and utilized. This effort kept tree killing below 1.5 trees per acre on about 150,000 acres for three consecutive years. Although 150 MMBF of the timber was sold, it was never harvested because of operator nonperformance. In 1971, a benefit-cost analysis showed that continued control costs could not be justified on the basis of benefits attributable to control. Consequently, the project was terminated. Since then, beetle populations in the "protected area" have increased several fold and, combined with the unchecked infestation to the east in Yellowstone National Park, the infestation continues its northerly advance into the 318 MMBF Moose Creek timber sale. Presently, more than 240 MMBF of lodgepole pine on that sale is still uncut and highly vulnerable to the building infestation.

OBJECTIVES

In order to determine priority of harvest, both timber manager and operator need to know the amount of mortality that has already occurred, the current level of infestation, and the rate and direction of increase. To accomplish these multiple objectives, a rather extensive ground survey was conducted in the most vulnerable lodgepole stands in portions of the Moose Creek timber sale during the fall of 1972. As an adjunct

to the survey, and with the realization that extensive ground data would be available as a reliable check, it was decided to test large scale 35mm color aerial photography as a supplemental evaluation tool.

Lately, 35mm aerial photography has been shown to have both practical and wide application in forestry (Zsilinsky, 1972; Neustein, et al., 1972; Harris, 1971; Klein, 1970). It has also been demonstrated that 35mm color aerial photography is an inexpensive and accurate method of detecting and quantifying trees killed by the mountain pine beetle in specific areas (Klein, 1973). However, one question remained: Can this small format method be used over relatively large areas in an operational capacity? To answer this question, factors such as photo scale control, on-the-ground plot location, and, most important, consistent photo interpretation have to be determined. Hopefully, if these problems can be resolved, a practical and inexpensive method of recording the infestation level and trend of the mountain pine beetle in lodgepole pine over extensive areas will result.

AREA

The area, approximately 25,000 acres in size, is on the northeast edge of the Targhee National Forest and extends from the Continental Divide in the north, south along the west boundary of Yellowstone National Park, to the South Fork of Middle Creek (Figure 1). This area is locally referred to as the Moose Creek Plateau. Practically the entire area is lodgepole pine type and elevations range from slightly less than 7,000 feet to more than 8,000 feet. The highest elevations are along the east edge, with the terrain falling rapidly away to the west, and less so to the south. Most of the area is bisected with many short, steep, east-west drainages. Between many of the larger drainages, the terrain is moderately rolling.

METHODS

Preflight Preparation. The area was first delimited on a topographic map. Five parallel flight lines one mile apart were drawn on the map. Elevations were taken at intervals along the intended flight line and then averaged to determine the mean elevation of each line. This established the flying height for each flight line. Plans were to establish photo plots in a 1-square-mile grid pattern.

Taking the Aerial Photography. All photography was taken from the right window of a Cessna Skymaster 337B with a specially constructed camera platform (Figure 2). The camera was a Nikon F with an Auto-Nikkor 85mm lens and a Nikkor LIA (skylight) filter. Film was Kodacolor X, a color negative film, in standard 36 exposure cassettes. The camera was kept level by a small fisheye bubble mounted on the

back plate; film advance and shutter release was by hand. Cycle interval to obtain stereo pairs and flying height (3,000 feet) to maintain a consistent scale (1:3300) was determined by a pocket computer (Figure 3). Ground speed was 80 MPH and the time between stereo pairs to achieve a one mile interval was 42 seconds. At times, this period was either lengthened or shortened to avoid ground shadows or shooting through clouds. A total of 49 photo plots were taken.

Photography was taken between 10:00 a.m. and 12:00 a.m. (MST) on August 31, 1972. Weather conditions were far from being ideal. There were several cumulus clouds in the area and an easterly crosswind that increased during the flight period. All five flight lines were photographed from east to west in a north-south direction. Orientation was difficult because of a lack of obvious terrain features; consequently, a road (Black Canyon) was used as a starting point. As the flight progressed and the crosswind increased, it became increasingly difficult to maintain a north-south direction and, as Figure 1 illustrates, drifting to the west occurred. Crab was easily compensated for by rotating the camera in its mount.

Photo Interpretation. All film was processed by Eastman Kodak Company (Palo Alto, California) and printed in a 3- x 5-inch (3R) format. A square 4.83-acre plot[1/] was delimited in the center of the effective overlap of each stereo pair. Counts of all new faders (1971 attacks) were made by an experienced interpreter using a standard pocket stereoscope.

The Small Ground Sample. Ten (22 percent) of the photo plots were randomly selected for ground checking. These plots were first located on 1:16,000 resource photography and then transferred to a small scale field map. Both resource photos and maps were used to locate the 35mm photo plot on the ground. Once the area was located, the 35mm photos were used exclusively (Figure 4).

Plot corners and boundaries were located and all recent bark beetle killed trees were located, examined, and classified as to year of attack. Each tree was then located and marked on the photo.

As a check on scale determination, at least one boundary of six (12 percent) plots was accurately measured with a 100-foot tape.

1/ Initially, a square 4-acre plot was planned, but because of a mathematical error in constructing a template, the actual area was 4.83 acres. The difference was not discovered until ground checking was completed. However, the same template was used on all plots and did not affect the final results, other than giving a larger sample.

In a few cases, it was more convenient to measure directly across the center of the plot.

An attempt was made to detect and measure all 1972 attacks in the 10 photo plots to determine the buildup ratio, but this was not accomplished because of the lack of personnel, time, and the threat of inclement weather (snow).

The Large Ground Sample. This cruise was independent of the photo survey and will be reported in detail in a separate report. At the outset, the areas were roughly stratified into commercial and non-commercial stands. Only the commercial lodgepole stands; i.e., those stands containing a preponderance of large diameter lodgepole pine were sampled (Figure 1). Bark beetle mortality was recorded in one-half-acre rectangular plots, one-half chain wide by 10 chains long, along continuous parallel strips 20 chains apart. Green stand data were taken in variable plots (BAF 10) established at the ends of each one-half-acre plot. Almost two-thirds of the area sampled by aerial photography was cruised in this manner.

RESULTS AND OBSERVATIONS

The small photo sample comparison shows that 93[1/] percent of the variance of photo estimates were associated with ground truth (Figure 5). With this consistent relationship established, it is possible to adjust the total photo sample by linear regression, as outlined by Weir, et al., (1966).

1. Mean tree count on all photo plots:

   $\bar{x}_1 = 3.43$ trees per plot

2. Mean tree count on photo plot subsample:

   $\bar{x}_2 = 5.50$ trees per plot

3. Mean tree count on small ground sample:

   $\bar{y}_2 = 5.20$ trees per plot

4. Plot size: calculated = 4.83 acres
   adjusted = 5.16 acres

5. Regression equation:

   $Y = a+bX = 0.36 + 0.87\ X$

1/ r^2 is commonly referred to as the coefficient of determination. It is simply the correlation coefficient ($r = 0.97$) squared.

6. Adjusted mean tree count:

$$yrd = \bar{y}_2 + b(\bar{x}_1, + \bar{x}_2) = 3.38 \text{ trees per plot}$$

7. Trees per acre (corrected for scale):

0.66 trees per acre

A slight reduction in the number of trees per acre was affected by sample plot size. Fixed measurements showed that actual plot size varied from 3.97 acres to 6.45 acres and averaged 5.16 acres, an increase of 6.8 percent over the calculated area. The final count was 0.66 1971 attacked trees per acre.

The large ground sample ranged from 0.46 to 3.94 trees per acre (see Figure 1), with a weighted average of 0.99 trees per acre. This increase was expected, for the ground survey was concentrated in areas highly susceptible to beetle attacks, while the photo method was more random, and sampled stands of all sizes and densities. Both surveys show a diminishing gradient of attack density from south to north, which corresponds closely with the known pattern of infestation movement. For example, the mean of plot totals in the south half of the photo area was 0.87 trees per acre, while the north half was 0.51 trees per acre. Figure 1 best illustrates the overall attack pattern of the large ground sample.

As an afterthought, it was decided to compare the diameter distribution of trees killed in both the small photo sample and large ground sample. Although not readily comparable because one was recorded by 1-inch class and the other by 2-inch class, there is still a strong similarity in distribution (Figure 6). In both samples, most mortality occurred in the mid-diameter range, from 11 to 14 inches d.b.h., with peak mortality occurring in the 12-13-inch d.b.h. class. There is little doubt that with uniform measurement, both distributions would be almost identical.

There was very little difficulty in differentiating 1971 attacks from 1970 attacks on the color photographs which can sometimes be a problem on the ground, especially if foliar characteristics are used exclusively. In some cases, particularly at high elevations, trees attacked and killed two years back will still retain their needles, and if a foliage condition is used as the main criteria, the results can be deceiving. Photographically, however, the difference is considerably more obvious[1/]. The most recent faders are orange to red-orange in color, while the 2-year-old faders are brown to red-brown. Dead tops were common to both categories, but they did not pose an interpretation problem. All stands in all photo plots had a very high incidence of top kill.

1/ During ground examinations, there are other signs used to estimate year of attack other than foliage characteristics.

CONCLUSIONS AND RECOMMENDATIONS

These results indicate that 1-year-old attacks by the mountain pine beetle in lodgepole pine can be detected and accurately quantified with large-scale 35mm color aerial photography, and that the system can be used operationally and inexpensively to record year-to-year trends over extensive areas.

Both photo and ground surveys showed that the 1971 infestation level on the Moose Creek Plateau were light (less than one tree per acre), that the infestation is increasing from south to north, and that most mortality is occurring in the mid-diameter classes. Additional data taken during the large ground survey show a buildup ratio of 2.5:1, meaning that there will be approximately 2.5 redtops per acre in this area in the summer of 1973. If this ratio[1/] is maintained during the 1973 beetle flight, the infestation level will exceed 7 trees per acre.

One stand characteristic that the photography brought out more so than the ground survey was the unusually high incidence of top kill. This phenomenon was not restricted to one or just a few areas, but it was dominant throughout all stands in the entire area. This will result in a very high cull factor for the area.

The photography was conducted at considerably less cost than the large ground survey, but the economics of the two methods are not comparable, for the ground survey resulted in much more detailed data. However, the cost advantage of this type of photographic survey, utilizing a conventional aircraft, a 35mm camera, off-the-shelf film, and standard processing, should be obvious.

PLANS FOR 1973

Plans are to duplicate the photographic survey in the same area in 1973 and each year after until the infestation subsides. The number of new faders in 1973 will be verified by double sampling and compared to the present 1972 attack level. Other technique refinements and operational factors that warrant investigation follow:

1. Photography will be taken during the last week of July rather than late August or early October to allow more time for ground checking.

1/ Attack ratio surveys and trend studies (Parker, 1972) over relatively extensive areas have shown that mountain pine beetle infestations in lodgepole pine increased at rates of 1:1 to 3:1 at the most. Buildup ratios exceeding the 3:1 rate would be most unusual.

2. Scale will be computed for each individual photo plot from elevations taken from topographic contour maps. The elevations of ground truth plots will be checked with a portable altimeter. In this manner, the area difference for each plot, regardless of its elevation, should not exceed $\pm$ 5 percent.

3. 1973 attacked trees will be recorded in those plots selected for ground checking. It is probable that this sample may require a smaller plot, perhaps only 1 or 2 acres. Hopefully, this multi-stage approach will yield a meaningful attack or buildup ratio.

4. An attempt will be made to determine total mortality and percent of top kill. These two characteristics may be difficult to separate. Most likely a smaller plot, perhaps 2 acres, will be used.

5. A simpler camera mount will be built and tested.

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APPENDIX

Figure 2. Vibration dampening 35mm aerial camera platform. Camera can be rotated to compensate for crab. Note "fisheye" level on backplate.

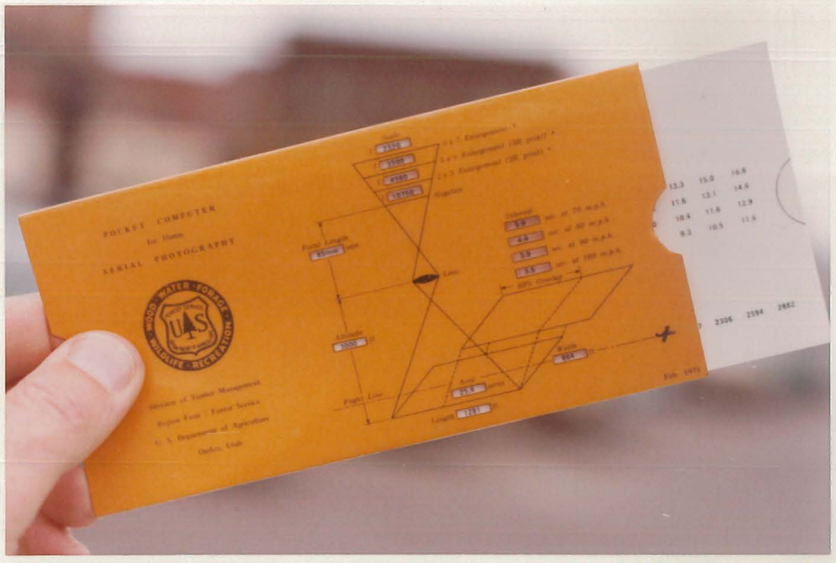


Figure 3. Rapid in-the-air calculations can be made with this handy pocket computer.

Figure 4. Portable stereoscope for viewing 35mm color prints (3R) in the field.

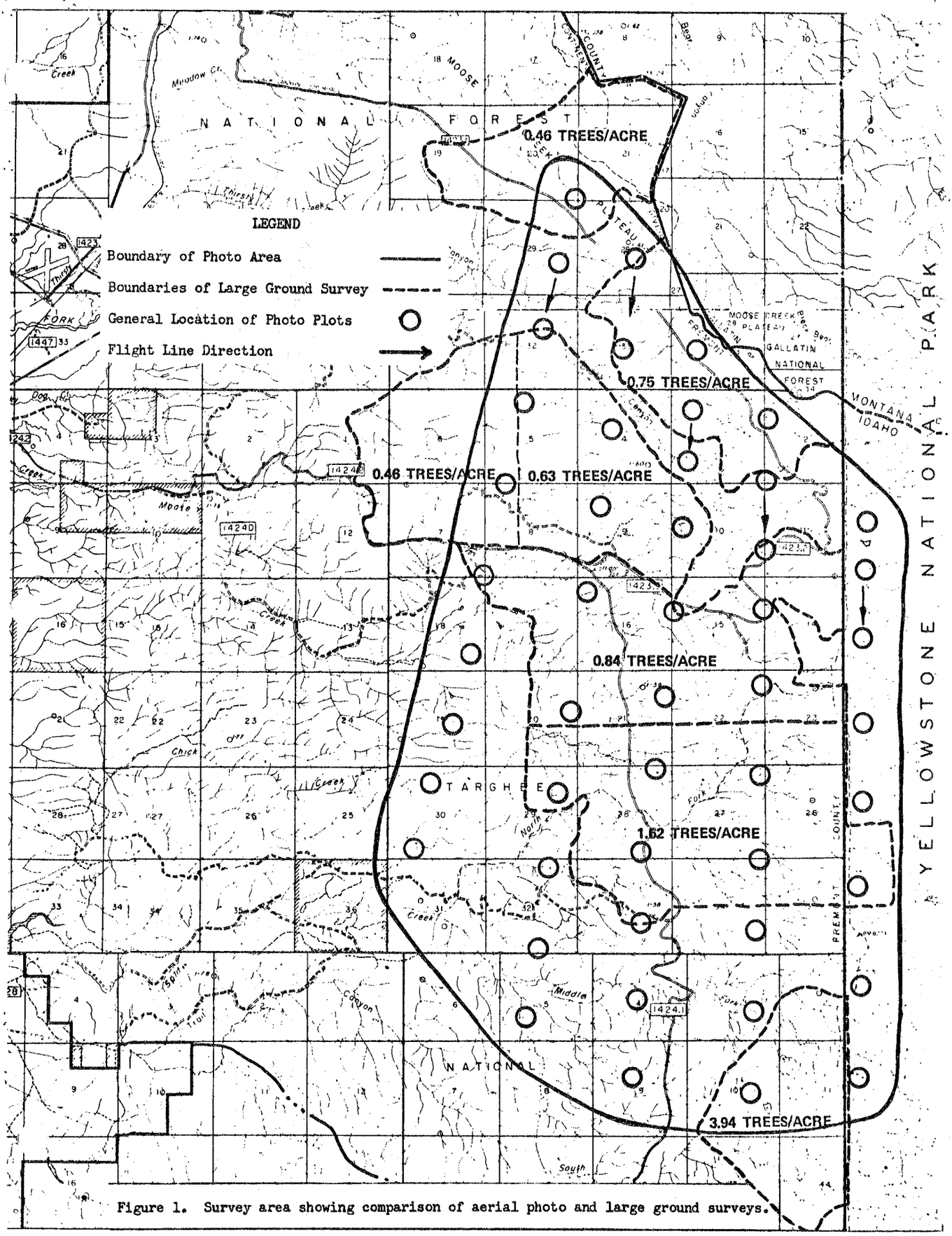
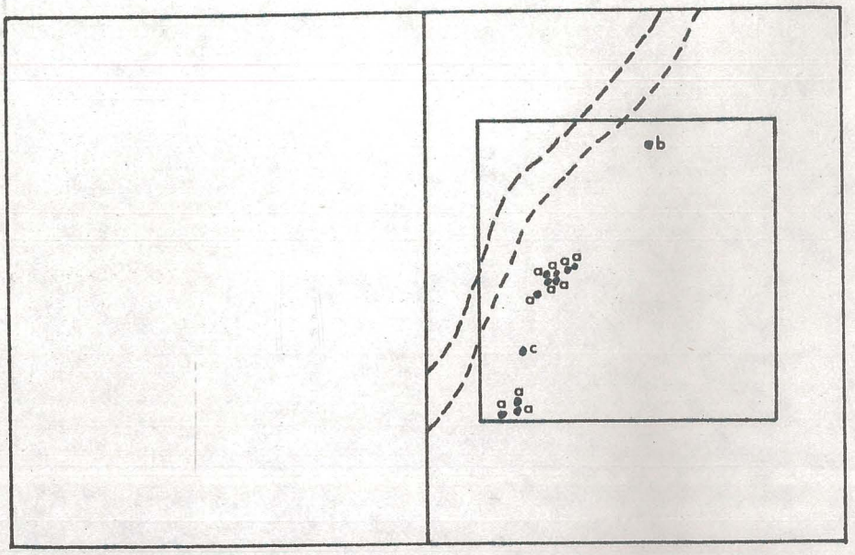


Figure 1. Survey area showing comparison of aerial photo and large ground surveys.



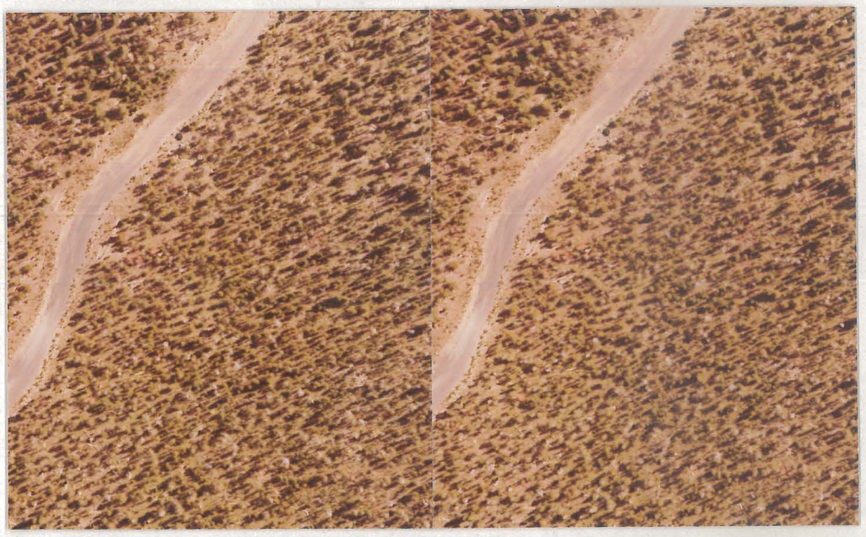
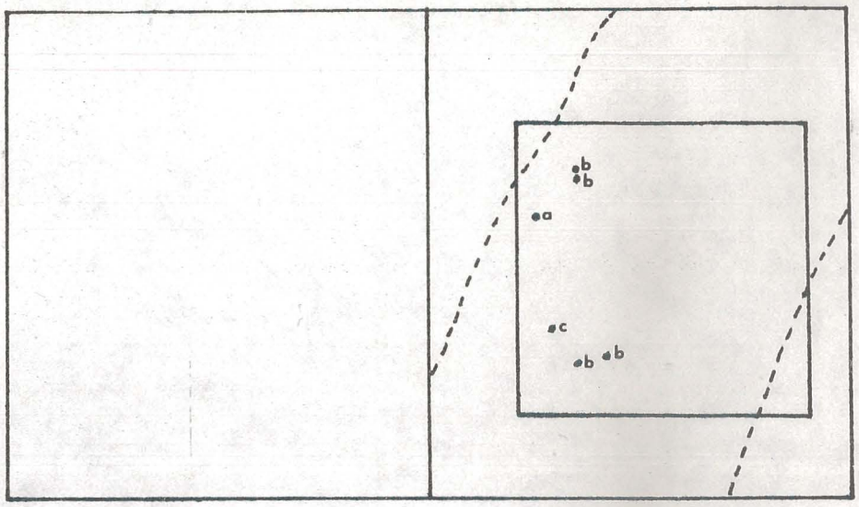


Figure 7. Stereogram of plot 3-14. a, 1972 faders (1971 attacks); b, 1971 fader (1970 attack); c, Ips kill (1971 attack). Note the incidence of top kill.



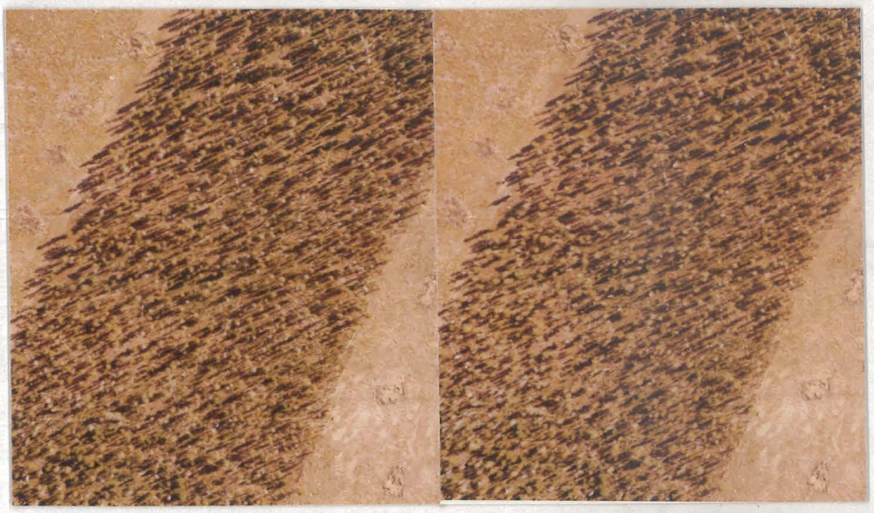


Figure 8. Stereogram of plot 4-23. Area of plot is 4.94 acres. a, 1972 fader (1971 attack); b, 1971 faders (1970 attacks); c, windthrown leaner. Note the incidence of top kill and windthrow.

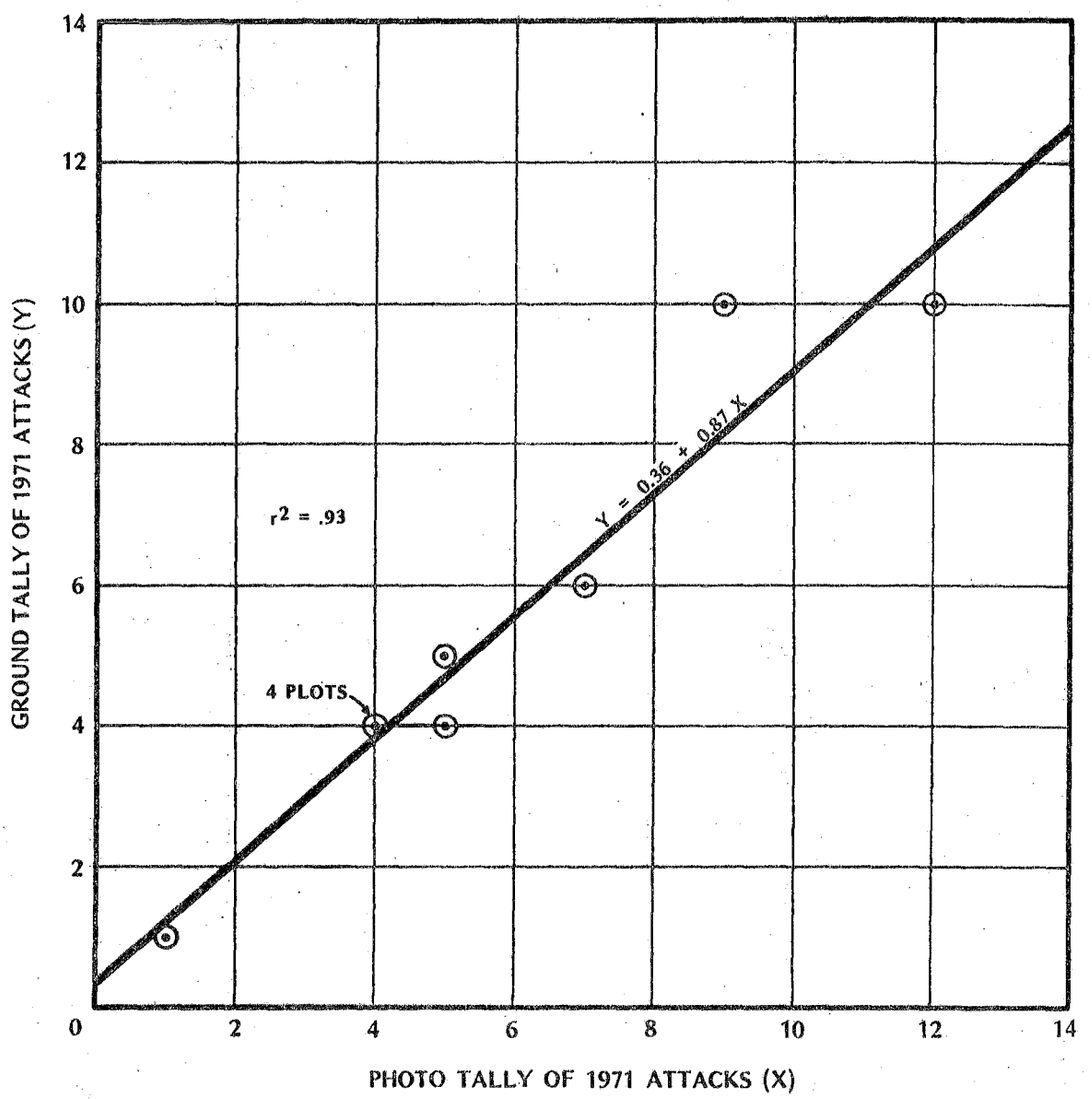


Figure 5. Comparison of photo-to-ground counts of lodgepole pine killed by the mountain pine beetle--Moose Creek Plateau, Targhee National Forest.

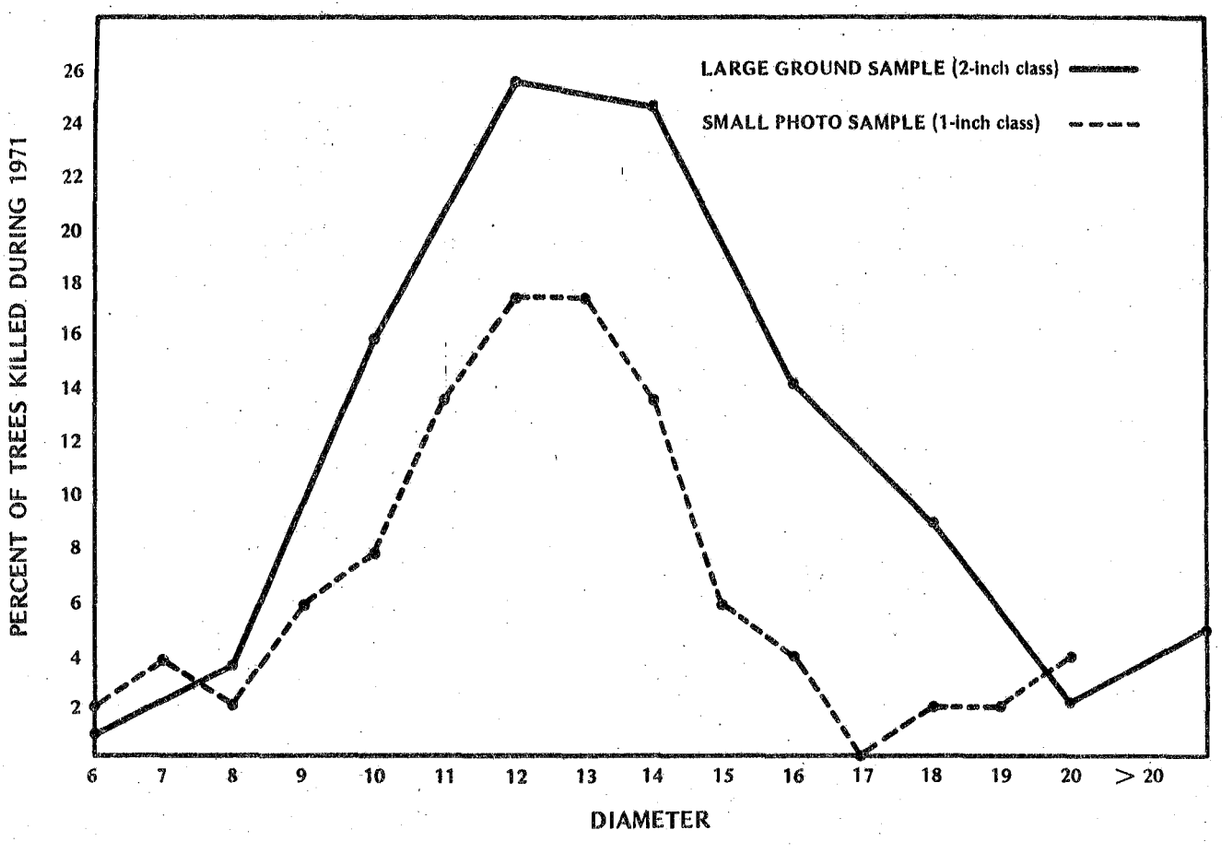


Figure 6. Diameter distribution of lodgepole pine killed by the mountain pine beetle during 1971--Moose Creek Plateau, Targhee National Forest.